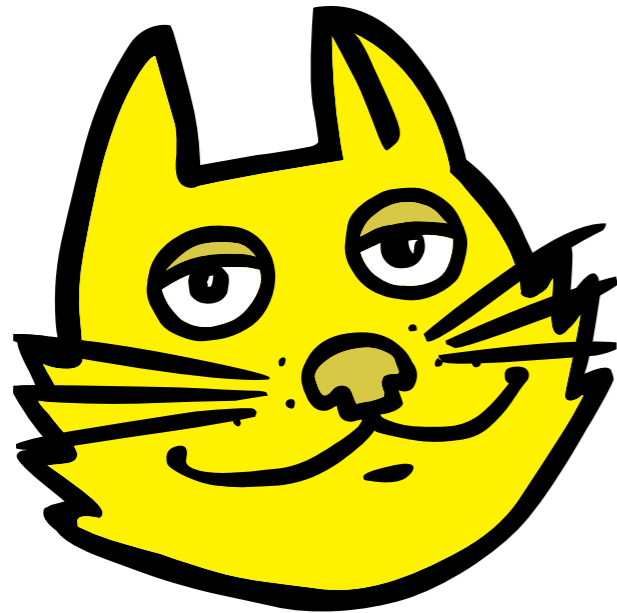


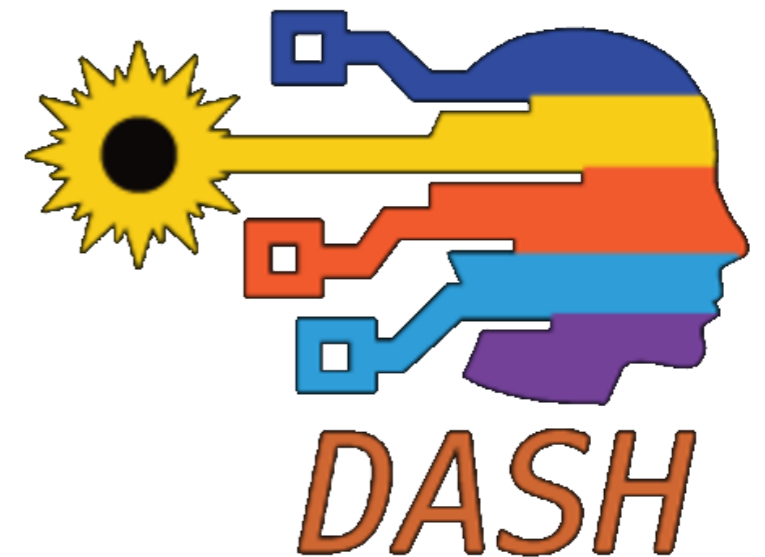
TOPCAT for Heliophysics



Mark Taylor (University of Bristol)

DASH 2024
ESAC, Spain

16 October 2024



\$Id: tchelio.tex,v 1.12 2024/10/15 20:09:10 mbt Exp \$

Summary

- What is TOPCAT?
- Why TOPCAT and heliophysics?
- Examples

TOPCAT Overview

TOPCAT = Tool for OPerations on Catalogues And Tables

“Does what you want with tables”

Suitable for:

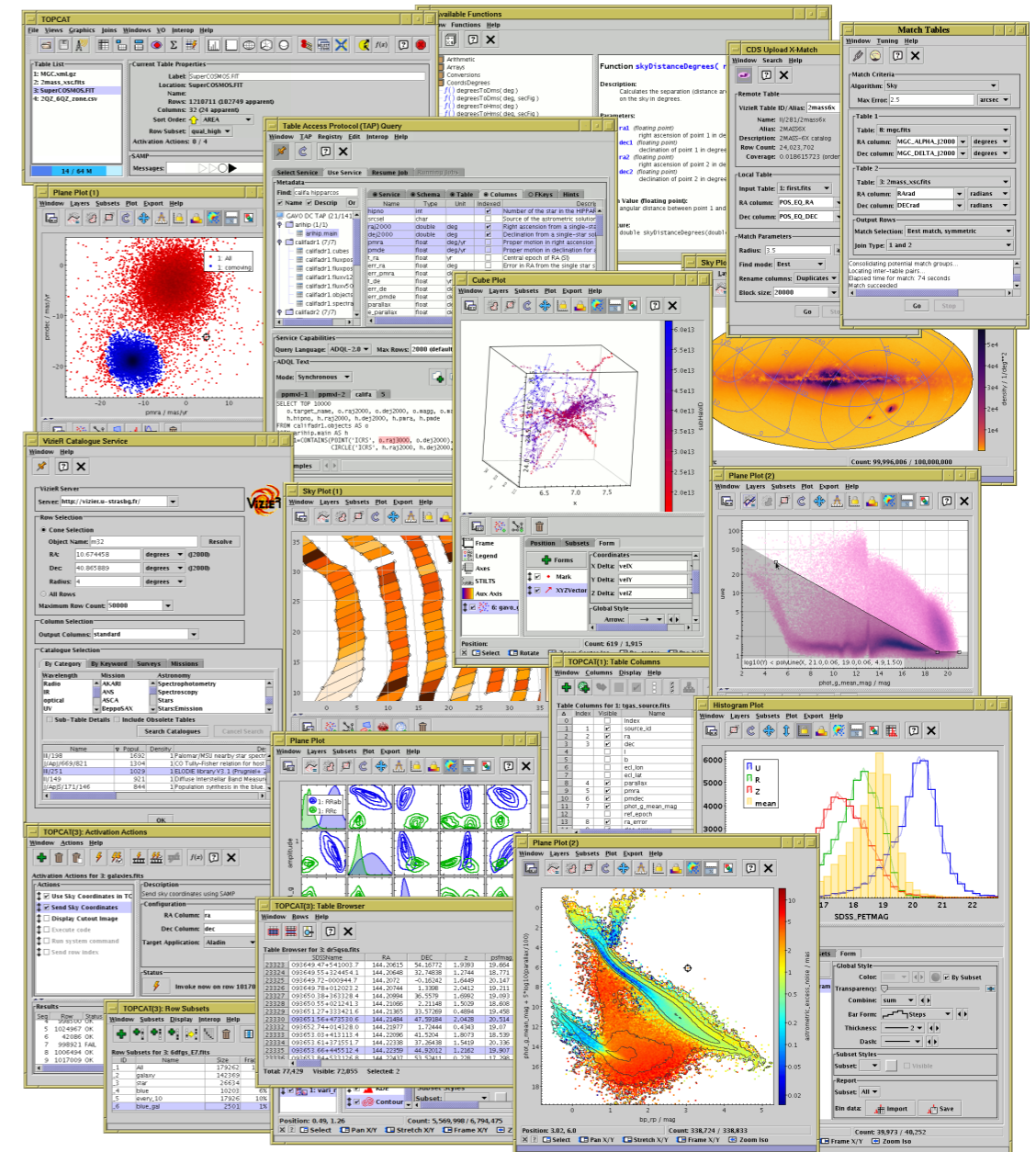
- Quick look at unfamiliar data
- In-depth analysis

Features:

- Interactive visualisation
- Large datasets (millions of rows, hundreds of columns)
- I/O (external services, file formats)
- Calculations (expression language)
- (+ more ...)
- (+ command-line sibling STILTS)

Overall aim:

- Makes table manipulation easy, so users can concentrate on doing science



TOPCAT Context

History

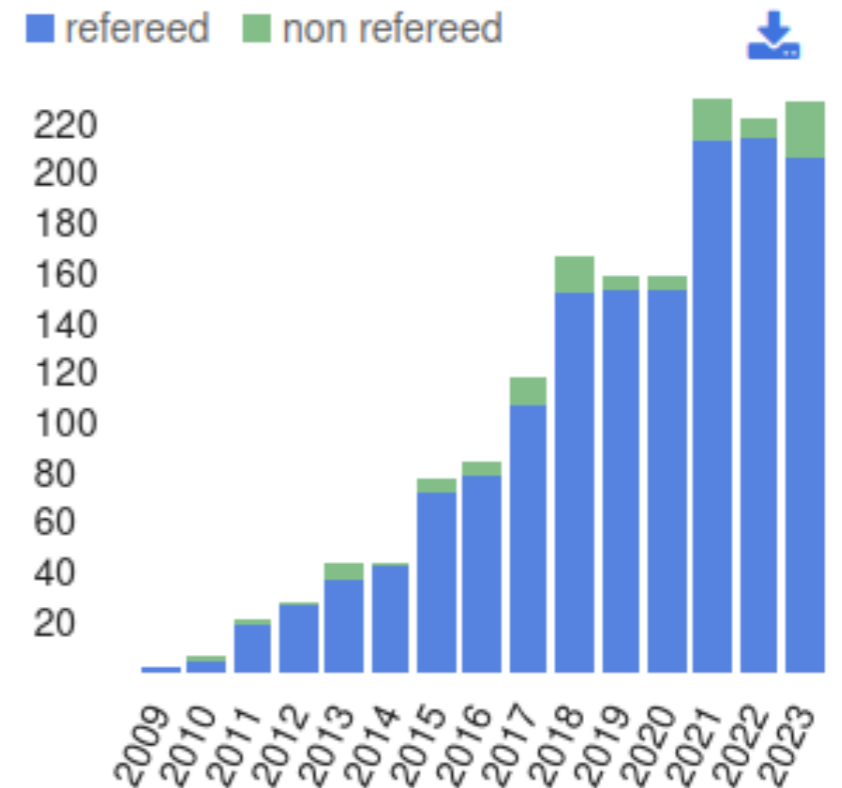
- Developed more or less continuously since ~2003
- Funded by numerous agencies/projects
- Associated with [Virtual Observatory \(VO\)](#) – early adopter of many VO standards

Development

- Platform: desktop pure Java (*easy deployment*)
- Development team: just me (*easy project management*)
- Open source, currently (L)GPL: <https://github.com/Starlink/starjava/>
- Short development cycle, encourage user involvement

Usage

- Cited by ~1800 papers ([2005ASPC..347...29T](#))
- Run from a few hundred unique IP addresses per day
- **Mostly astronomers**
 - ▷ But some users in **heliophysics**, planetary science, others
- **Typically source catalogues**
 - ▷ But other tables too: **time series**, event lists, simulations, SSOs, spectra, anything in a DB, ...



Citations (NASA ADS)

Example

*Identify and analyse members of Pleiades
open cluster using Gaia archive*

Example

Available Cone Services

Registry:

Keywords:

Match Fields: Short Name Title Subjects ID Publisher Descr

Accept Resource Lists

Short Name	Title	
ARI-Gaia	ARI's Cone Search Service for the last Gaia Data Release (DR3)	Gai
ARI-Gaia	ARI's Cone Search Service for Gaia EDR3	Gai
DR3 lite Cone	Gaia DR3 Lite Cone Search	sta
DR3 lite Cone	Gaia DR3 Lite Cone Search	pro
DR3 lite+dist	Gaia DR3 Lite Distances Subset Cone Search	sta
GAIA DR3	Gaia DR3 at ESA	Gai
GAIA EDR3	Gaia EDR3 at ESA	Gai

AccessURL	Description	Version
https://gaia.ari.uni-heidelbe...		

Resource Count: 42

Cone Parameters

Cone URL:

Object Name:

RA: (J2000) Accept Sky Positions

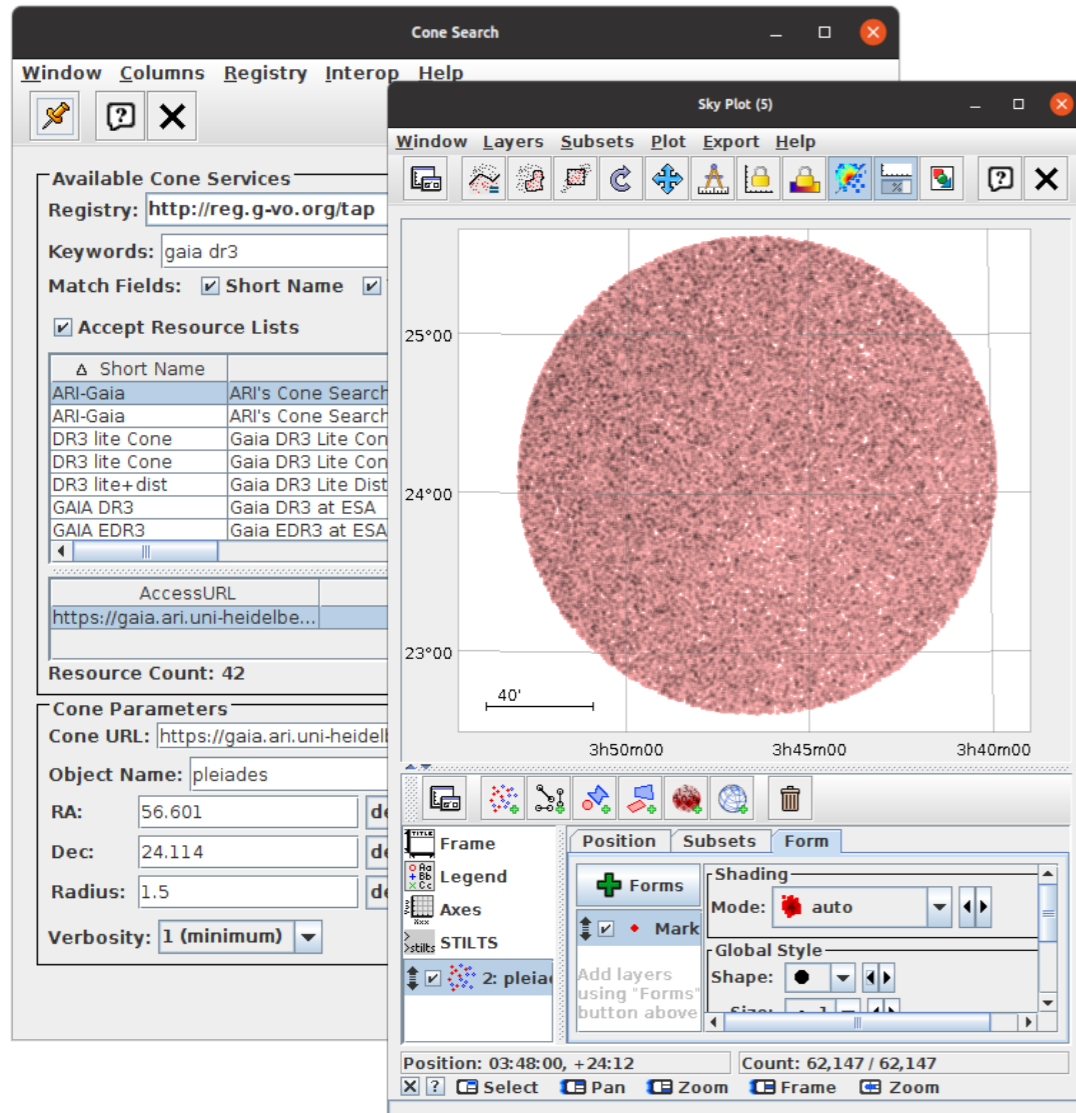
Dec: (J2000)

Radius:

Verbosity:

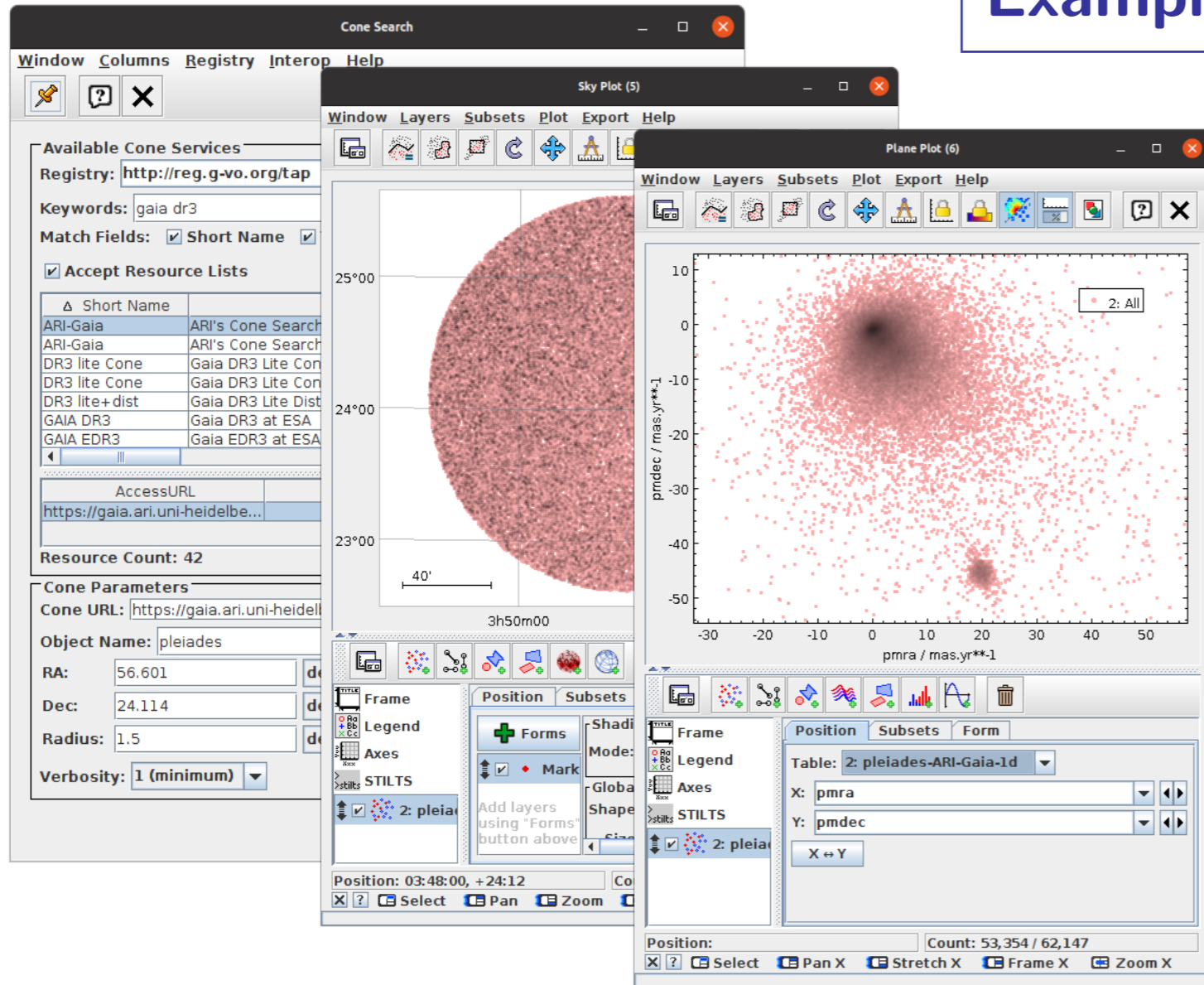
Identify and analyse members of Pleiades open cluster using Gaia archive

Example



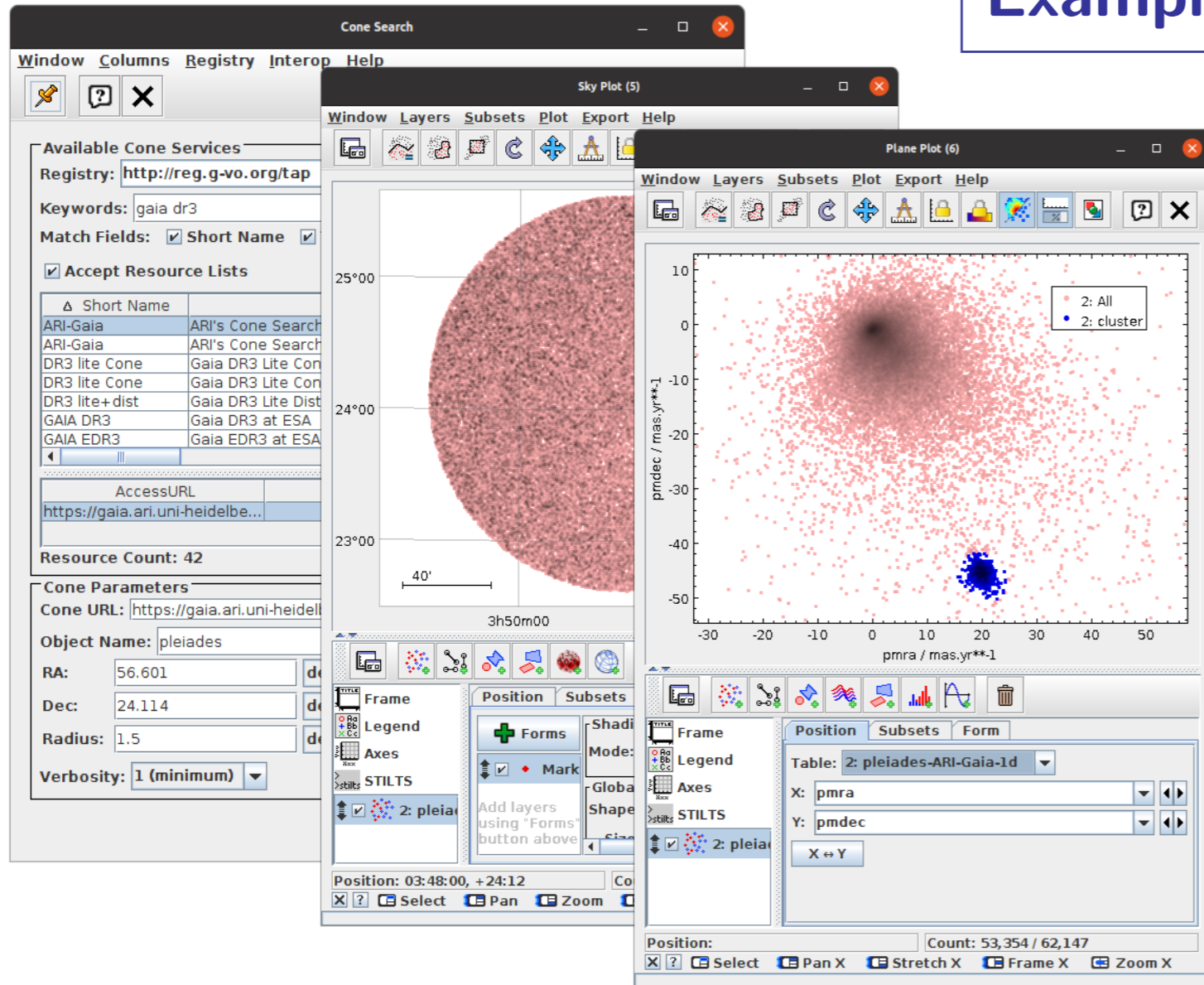
Identify and analyse members of Pleiades open cluster using Gaia archive

Example



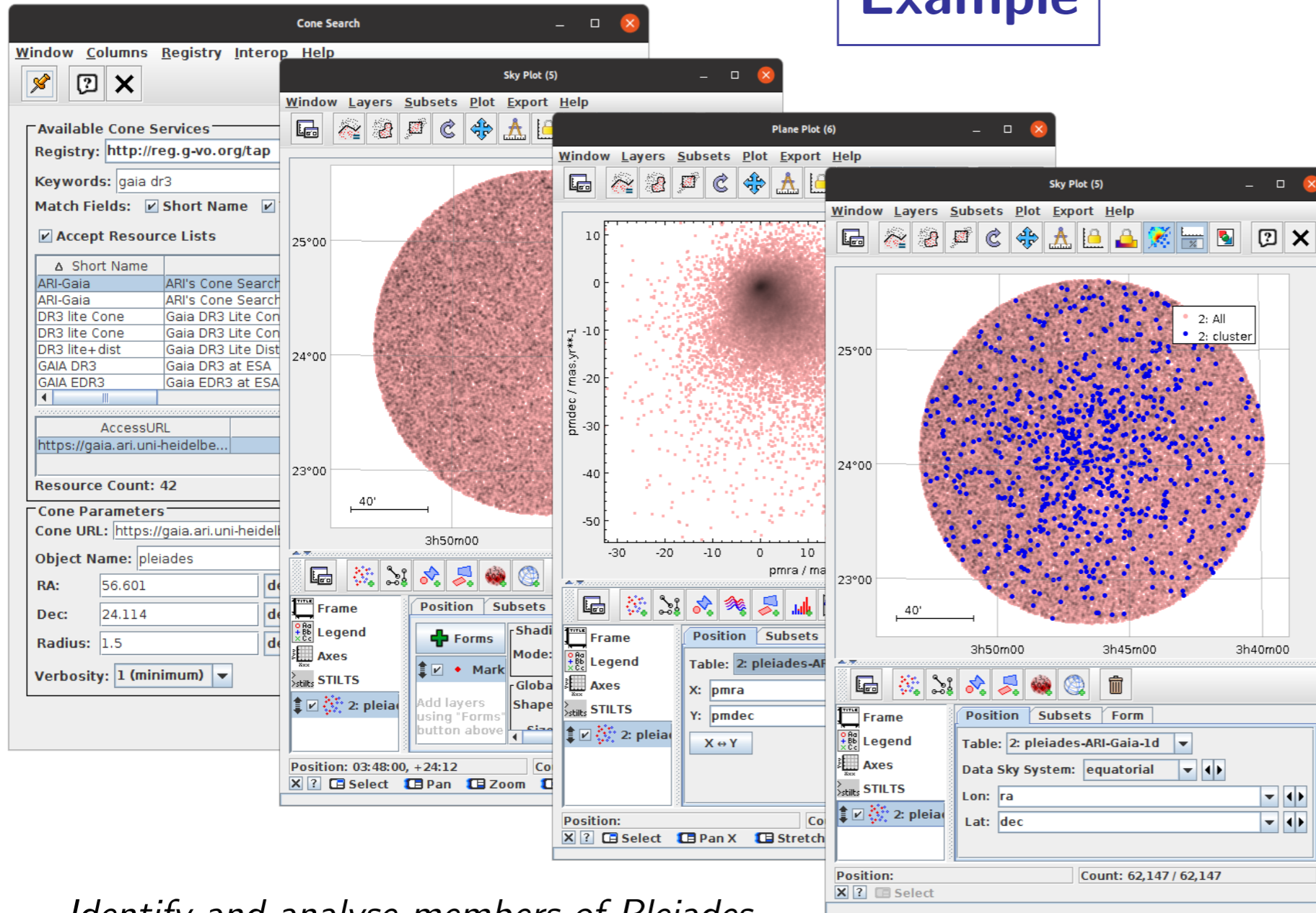
Identify and analyse members of Pleiades open cluster using Gaia archive

Example



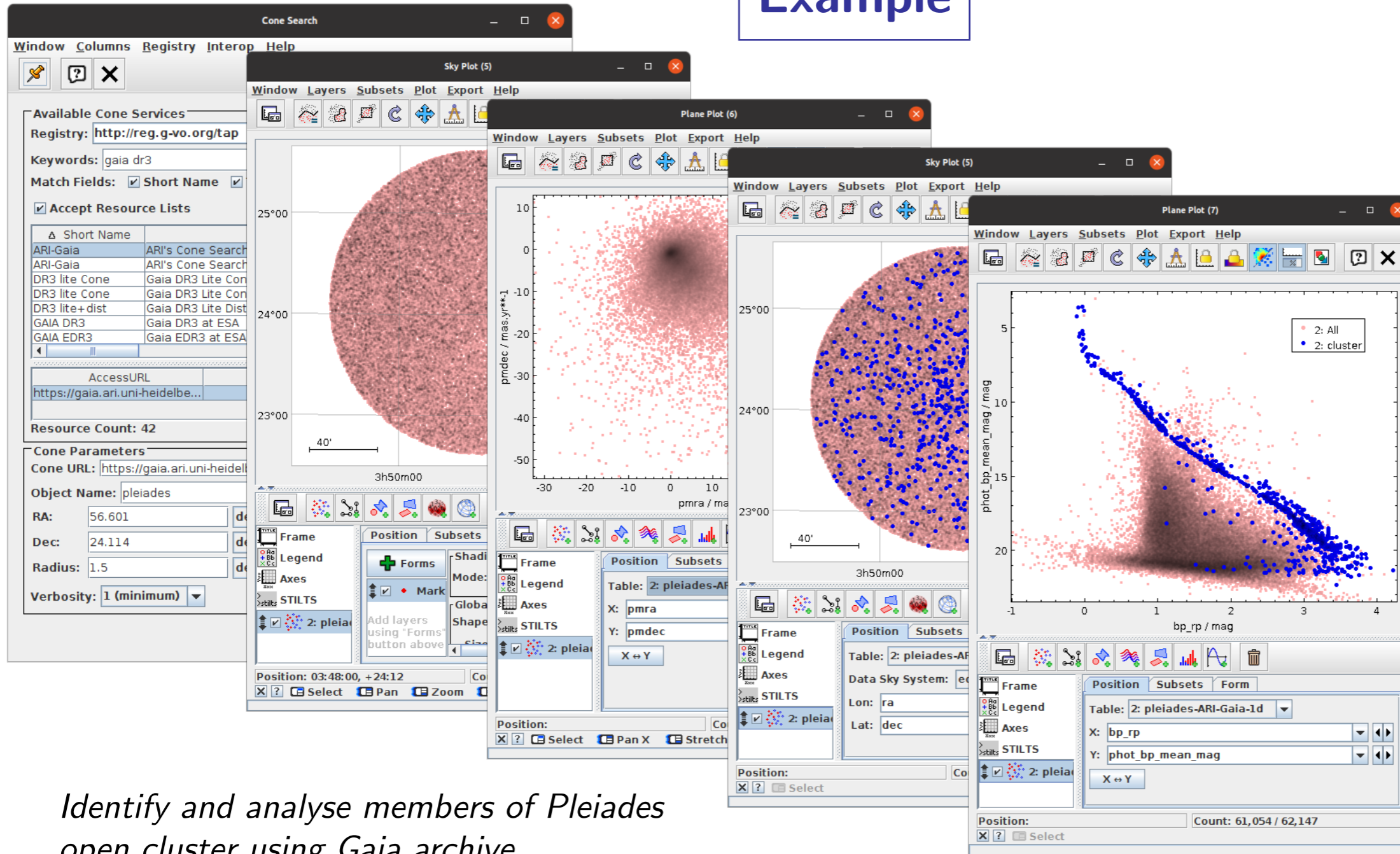
*Identify and analyse members of Pleiades
open cluster using Gaia archive*

Example



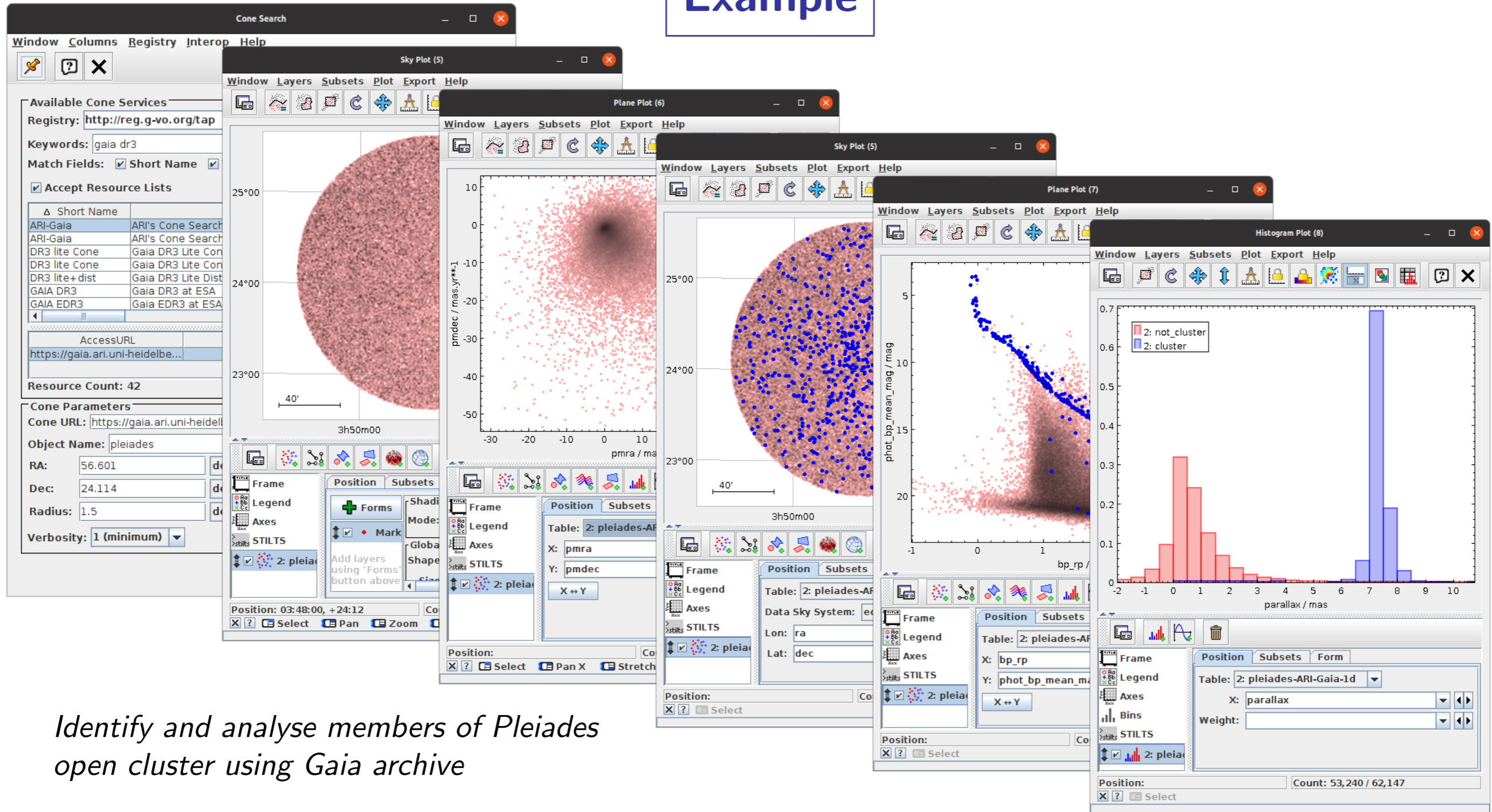
Identify and analyse members of Pleiades open cluster using Gaia archive

Example



Identify and analyse members of Pleiades open cluster using Gaia archive

Example



Identify and analyse members of Pleiades open cluster using Gaia archive

Why TOPCAT and Heliophysics?

TOPCAT: why heliophysics?

- Helio has lots of tables (mainly time series?)
- Some overlap of users with astronomy
- IVOA may adopt/recommend HAPI for time-series data in the VO

Heliophysics: why TOPCAT?

- TOPCAT will *not* replace existing helio tools
- But it provides some complementary features
 - ▷ Different plot types (3D, corner plot, density maps, ...)
 - ▷ Very large static tables
 - ▷ Flexible calculations (expression language)
 - ▷ File format conversions
 - ▷ VO data access

Features

TOPCAT capabilities **specific** to heliophysics data and services:

- HAPI service interface
- CDF file input
- FITS file I/O
- PDS4 file input
- TAP/EPN-TAP service interface
- TFCAT region display (partial)
- SAMP (interoperate with AutoPlot, AMDA, JHelioViewer, some web pages, ...)

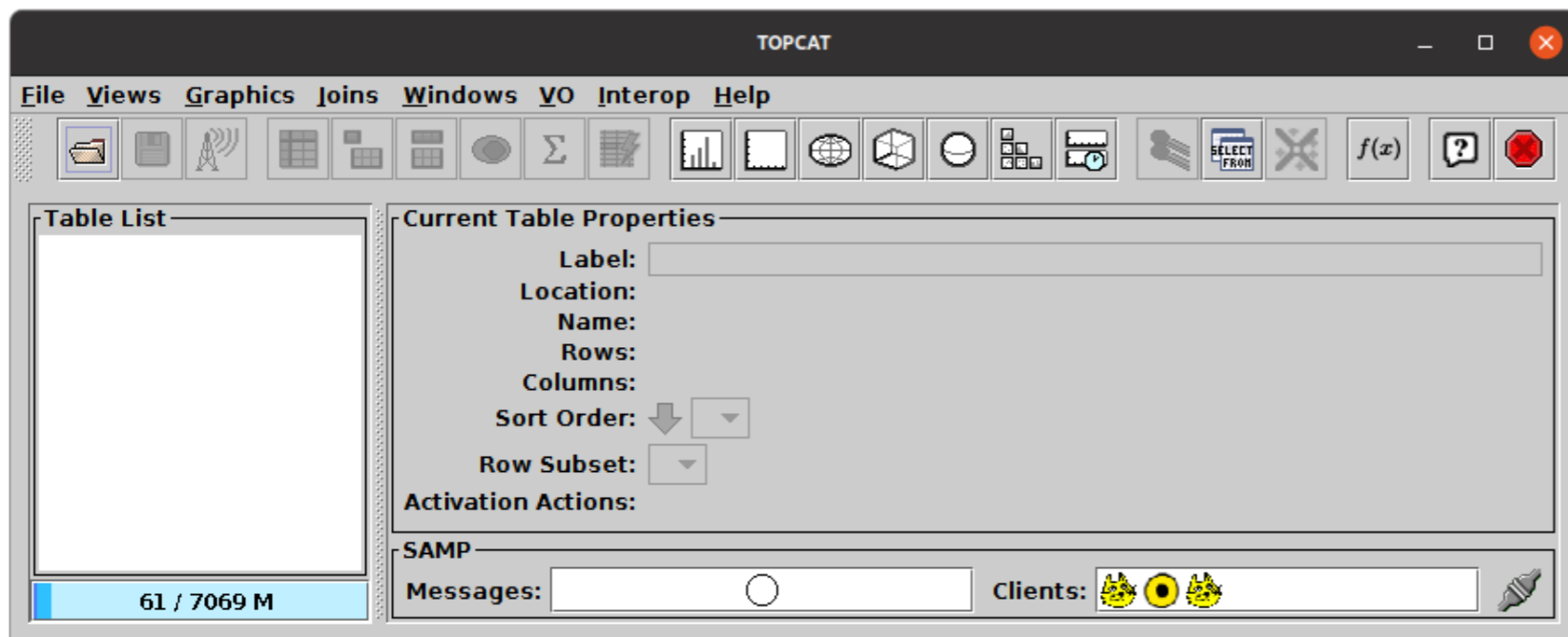
TOPCAT capabilities **relevant** to heliophysics:

- Other file format I/O (VOTable, (E)CSV, ASCII, ...)
- Interactive visualisation, many options, linked views
- Multi-million row tables
- Column calculations (extensible expression language)
- Table data/metadata viewing and manipulation

Heliophysics Example: Load

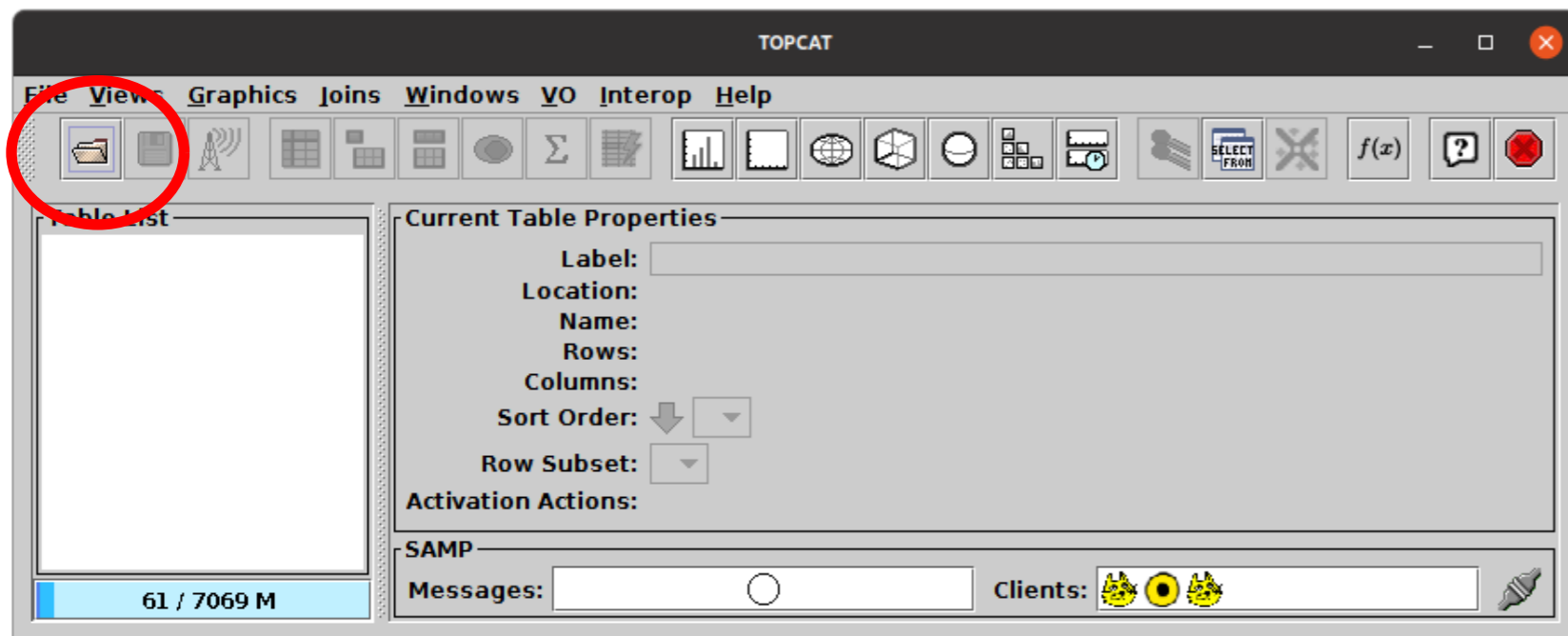
Load data from HAPI service

Heliophysics Example: Load



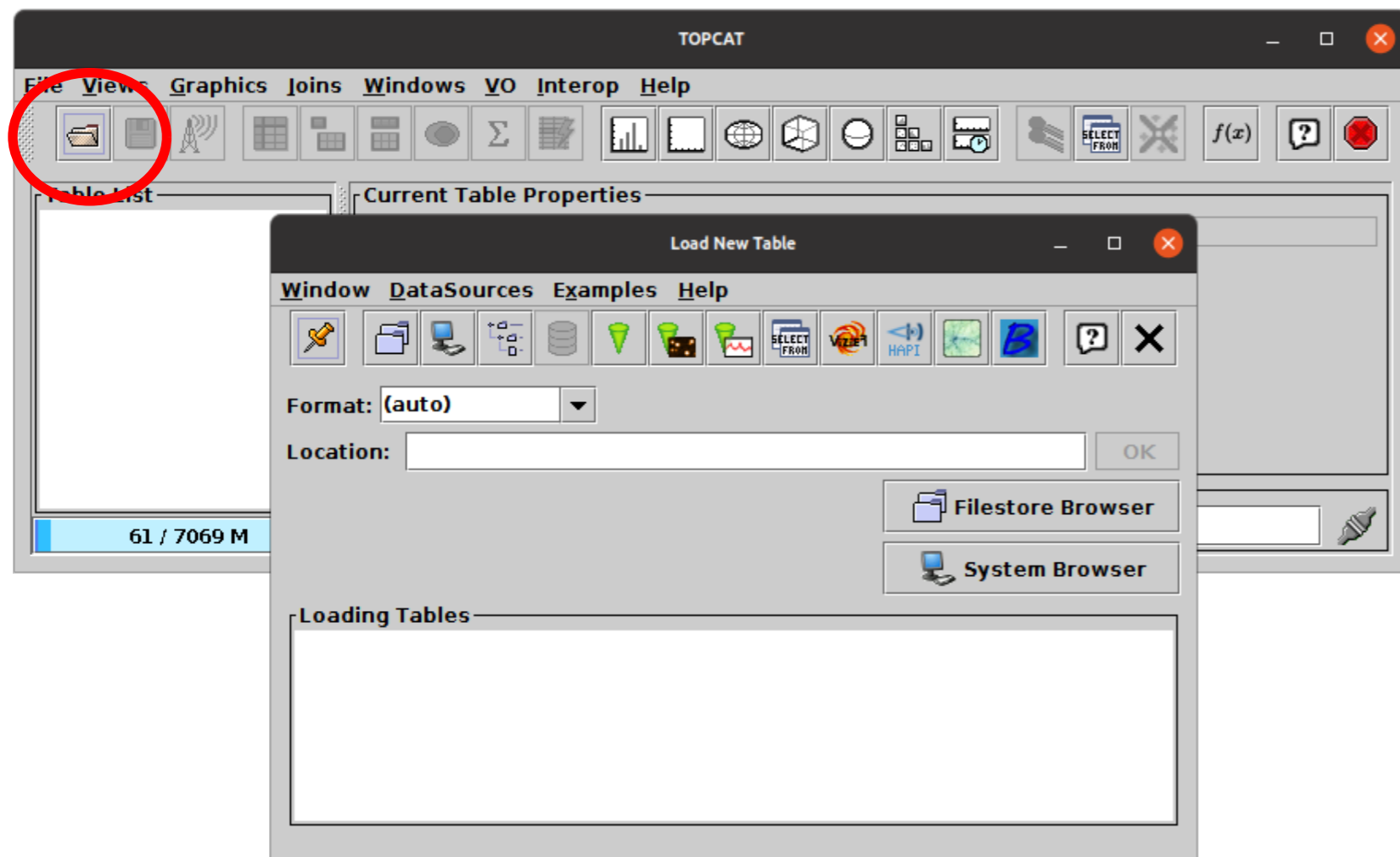
Load data from HAPI service

Heliophysics Example: Load



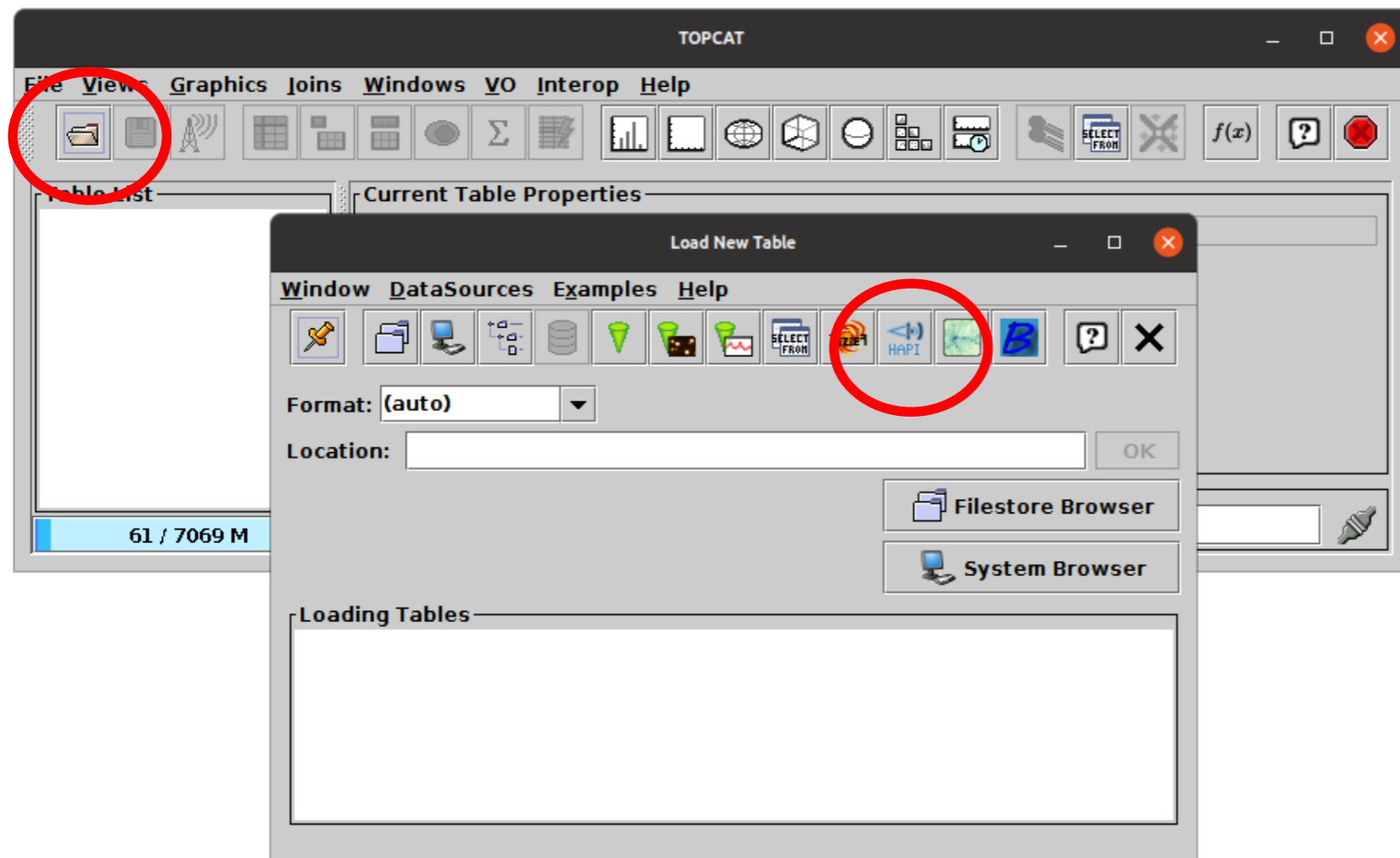
Load data from HAPI service

Heliophysics Example: Load



Load data from HAPI service

Heliophysics Example: Load



Load data from HAPI service

Heliophysics Example: Load

The image shows two overlapping windows from the TOPCAT software. The background window is the 'Load New Table' dialog, and the foreground window is the 'HAPI Query' configuration window.

Load New Table Dialog:

- Menu: Window, DataSources, Examples, Help
- Format: (auto)
- Location: [Empty text field]
- Buttons: Filestore Browser, System Browser
- Toolbar: Includes a red circle around the HAPI icon.

HAPI Query Window:

- Service Selection: HAPI Server: CDAWeb, HAPI URL: https://cdaweb.gsfc.nasa.gov/hapi, Chunk Limit: 1
- Datasets: ISEE-3_MAG_1MIN_MAGNETIC_FIELD, ISEE1_4SEC_MFI, ISEE1_60SEC_MFI, ISEE1_H0_FE (selected), ISEE1_H1_FPE. Filter: isee (14 / 3401)
- Dataset Parameters Table:

Include	Name	Type	Size	Units	
<input checked="" type="checkbox"/>	Time	isotime	24	UTC	
<input type="checkbox"/>	HARVEY STATUS	integer			Harvey Experiment Status (0 = Off)
<input type="checkbox"/>	MOZER STATUS	integer			Mozer Experiment Status (0 = Off)
<input type="checkbox"/>	MODE	integer			Instrument Mode
<input type="checkbox"/>	FORMAT	integer			Format
<input checked="" type="checkbox"/>	SPIN PERIOD	double		Seconds	Spin Period
<input checked="" type="checkbox"/>	THEO_GSE_X	double		km	Spacecraft Position X (GSE)
<input checked="" type="checkbox"/>	THEO_GSE_Y	double		km	Spacecraft Position Y (GSE)
<input checked="" type="checkbox"/>	THEO_GSE_Z	double		km	Spacecraft Position Z (GSE)
<input checked="" type="checkbox"/>	FN	double	[6]	cm ⁻³	Electron density at 0.5 sec resolution

Dataset Metadata:

- Cadence:
- Max Duration:
- Resource URL: https://cdaweb.gsfc.nasa.gov/misc/Notes1.html#ISEE1_H0_FE
- Interval:

Start Date: 1979-05-04T13:22:04 >= 1977-10-29T12:41:25Z
Stop Date: 1979-06-03T23:59:51Z <= 1979-06-03T23:59:51Z

Timeline: 1978, 1979, 1sec, 1min, 1hr, 1day, 1m, 1yr

OK

Load data from HAPI service

Heliophysics Example: Data and Metadata

TOPCAT(1): Table Browser

Window Rows Help

Table Browser for 1: isee.hapi

	Time	MODE	THEO_GSE_X	THEO_GSE_Y	THEO_GSE_Z	FN
63993	1979-05-29T16:32:54.418Z	0	-63500.71875	1.164666E5	28610.53906	(4.593812688330109, 4.6640675559
63994	1979-05-29T16:33:03.544Z	0	-63507.15625	1.164684E5	28609.08594	(4.987731847594904, 4.9887853282
63995	1979-05-29T16:33:12.670Z	0	-63513.59766	1.164704E5	28607.62891	(4.473382673968097, 4.7110327747
63996	1979-05-29T16:33:21.796Z	0	-63520.04297	1.164723E5	28606.17578	(3.8419488384657434, 4.007412913
63997	1979-05-29T16:33:30.921Z	0	-63526.48047	1.164742E5	28604.71875	(4.0240833936109155, 4.192541768
63998	1979-05-29T16:33:40.046Z	0	-63532.92578	1.164761E5	28603.26172	(3.9173937589493733, 3.934870148
63999	1979-05-29T16:33:49.172Z	0	-63539.37109	1.164779E5	28601.80469	(3.8812517507534308, 3.987048935
64000	1979-05-29T16:33:58.298Z	0	-63545.8125	1.164799E5	28600.35156	(3.575377564958966, 3.6994704654
64001	1979-05-29T16:34:07.424Z	0	-63552.23438	1.164818E5	28598.89453	(3.4464081084375104, 3.652977171
64002	1979-05-29T16:34:16.549Z	0	-63558.65625	1.164838E5	28597.4375	(3.6279267912756543, 3.779943672
64003	1979-05-29T16:34:25.674Z	0	-63565.07422	1.164856E5	28595.97656	(3.3726941238570753, 3.577191458
64004	1979-05-29T16:34:34.800Z	0	-63571.48828	1.164875E5	28594.51562	(2.9074679787035924, 3.063317329
64005	1979-05-29T16:34:43.926Z	0	-63577.91016	1.164894E5	28593.0625	(2.704318643993033, 2.7295989491
64006	1979-05-29T16:34:53.051Z	0	-63584.32812	1.164912E5	28591.60156	(2.9169052993450295, 3.054920040
64007	1979-05-29T16:35:02.177Z	0	-63590.79297	1.164931E5	28590.14844	(2.722985604047868, 2.8025764551
64008	1979-05-29T16:35:11.302Z	0	-63597.20312	1.164951E5	28588.67969	(2.675012044750583, 2.6900048897
64009	1979-05-29T16:35:20.428Z	0	-63603.62109	1.164969E5	28587.22266	(2.987562818509198, 3.0128676278
64010	1979-05-29T16:35:29.554Z	0	-63610.03516	1.164988E5	28585.76172	(2.774531644625088, 3.0335519337
64011	1979-05-29T16:35:38.679Z	0	-63616.44922	1.165007E5	28584.29688	(2.4694905799268834, 2.645362121
64012	1979-05-29T16:35:47.805Z	0	-63622.86328	1.165026E5	28582.83594	(2.6422943524234985, 2.703412006
64013	1979-05-29T16:35:56.930Z	0	-63629.28125	1.165044E5	28581.37891	(2.6582354717801864, 2.762346772
64014	1979-05-29T16:36:06.057Z	0	-63635.70312	1.165063E5	28579.91797	(2.8184021204436576, 3.013099159
64015	1979-05-29T16:36:15.182Z	0	-63642.13672	1.165082E5	28578.44922	(2.885481980100204, 3.0662454475
64016	1979-05-29T16:36:24.308Z	0	-63648.56641	1.165101E5	28576.98828	(2.844815081613072, 2.8402001062
64017	1979-05-29T16:36:33.433Z	0	-63654.99219	1.165119E5	28575.52734	(2.616492253255343, 2.5622070782

Total: 92,749 Visible: 92,749 Selected: 0

CDAWeb ISEE_H0_FE data

Heliophysics Example: Data and Metadata

TOPCAT(1): Table Browser

Window Rows Help

Table Browser for 1: isee.hapi

	Time	MODE	THEO_GSE_X	THEO_GSE_Y	THEO_GSE_Z	
63993	1979-05-29T16:32:54.418Z	0	-63500.71875	1.164666E5	28610.53906	(4.59)
63994	1979-05-29T16:33:03.544Z	0	-63507.15625	1.164684E5	28609.08594	(4.98)
63995	1979-05-29T16:33:12.670Z	0	-63513.59766	1.164704E5	28607.62891	(4.47)
63996	1979-05-29T16:33:21.796Z	0	-63520.04297	1.164723E5	28606.17578	(3.84)
63997	1979-05-29T16:33:30.921Z	0	-63526.48047	1.164742E5	28604.71875	(4.02)
63998	1979-05-29T16:33:40.046Z	0	-63532.92578	1.164761E5	28603.26172	(3.91)
63999	1979-05-29T16:33:49.172Z	0	-63539.37109	1.164779E5	28601.80469	(3.88)
64000	1979-05-29T16:33:58.298Z	0	-63545.8125	1.164799E5	28600.35156	(3.57)
64001	1979-05-29T16:34:07.424Z	0	-63552.23438	1.164818E5	28598.89453	(3.44)
64002	1979-05-29T16:34:16.549Z	0	-63558.65625	1.164838E5	28597.4375	(3.62)
64003	1979-05-29T16:34:25.674Z	0	-63565.07422	1.164856E5	28595.97656	(3.37)
64004	1979-05-29T16:34:34.800Z	0	-63571.48828	1.164875E5	28594.51562	(2.90)
64005	1979-05-29T16:34:43.926Z	0	-63577.91016	1.164894E5	28593.0625	(2.70)
64006	1979-05-29T16:34:53.051Z	0	-63584.32812	1.164912E5	28591.60156	(2.91)
64007	1979-05-29T16:35:02.177Z	0	-63590.79297	1.164931E5	28590.14844	(2.72)
64008	1979-05-29T16:35:11.302Z	0	-63597.20312	1.164951E5	28588.67969	(2.67)
64009	1979-05-29T16:35:20.428Z	0	-63603.62109	1.164969E5	28587.22266	(2.98)
64010	1979-05-29T16:35:29.554Z	0	-63610.03516	1.164988E5	28585.76172	(2.77)
64011	1979-05-29T16:35:38.679Z	0	-63616.44922	1.165007E5	28584.29688	(2.46)
64012	1979-05-29T16:35:47.805Z	0	-63622.86328	1.165026E5	28582.83594	(2.64)
64013	1979-05-29T16:35:56.930Z	0	-63629.28125	1.165044E5	28581.37891	(2.65)
64014	1979-05-29T16:36:06.057Z	0	-63635.70312	1.165063E5	28579.91797	(2.81)
64015	1979-05-29T16:36:15.182Z	0	-63642.13672	1.165082E5	28578.44922	(2.88)
64016	1979-05-29T16:36:24.308Z	0	-63648.56641	1.165101E5	28576.98828	(2.84)
64017	1979-05-29T16:36:33.433Z	0	-63654.99219	1.165119E5	28575.52734	(2.61)

Total: 92,749 Visible: 92,749 Selected: 0

TOPCAT(1): Table Columns

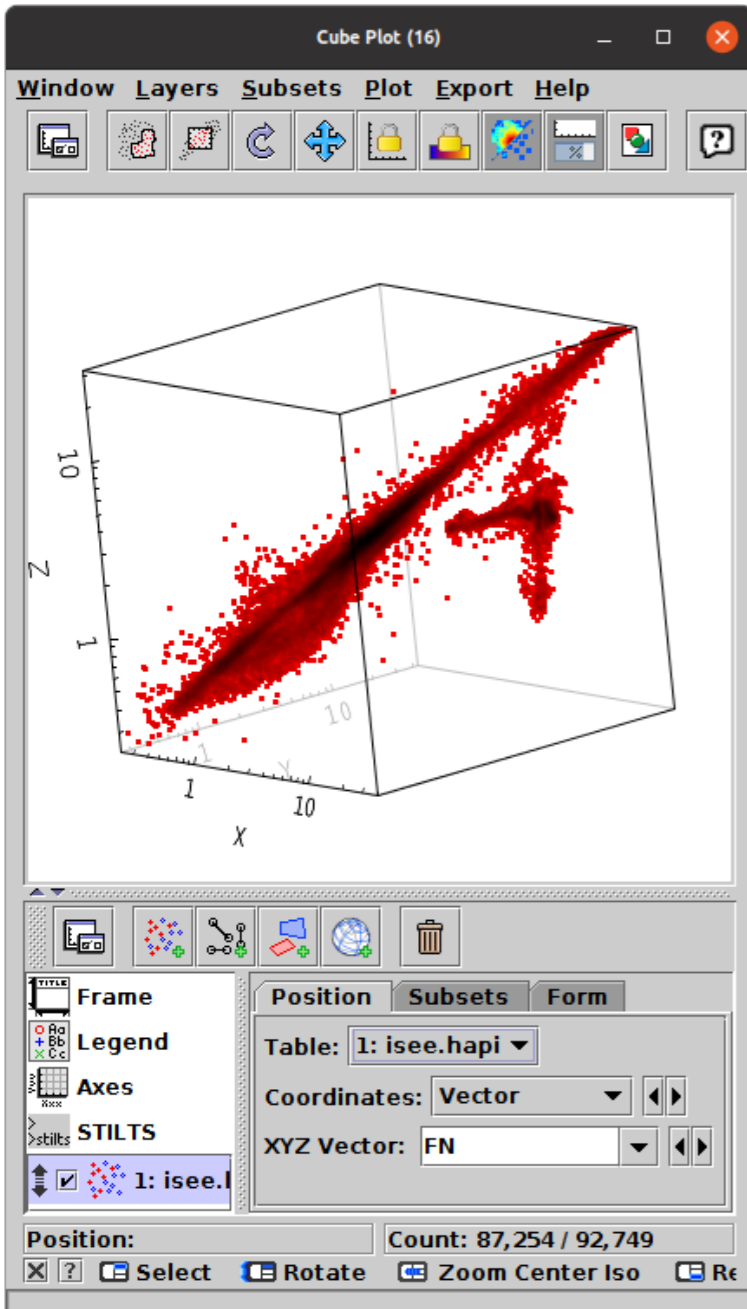
Window Columns Display Export Help

Table Columns for 1: isee.hapi

Δ	Index	Visible	Name	Class	Shape	Units	Description
0		<input type="checkbox"/>	Index	Long			Table row index
1	1	<input checked="" type="checkbox"/>	Time	String			
2		<input type="checkbox"/>	HARVEY STATUS	Integer			Harvey Experiment Status (0 = Off)
3		<input type="checkbox"/>	MOZER STATUS	Integer			Mozer Experiment Status (0 = Off)
4	2	<input checked="" type="checkbox"/>	MODE	Integer			Instrument Mode
5		<input type="checkbox"/>	FORMAT	Integer			Format
6		<input type="checkbox"/>	SPIN PERIOD	Double		Seconds	Spin Period
7	3	<input checked="" type="checkbox"/>	THEO_GSE_X	Double		km	Spacecraft Position X (GSE)
8	4	<input checked="" type="checkbox"/>	THEO_GSE_Y	Double		km	Spacecraft Position Y (GSE)
9	5	<input checked="" type="checkbox"/>	THEO_GSE_Z	Double		km	Spacecraft Position Z (GSE)
10	6	<input checked="" type="checkbox"/>	FN	double[]	6	cm ⁻³	Electron density at 0.5 sec resolution (60-deg se
11	7	<input checked="" type="checkbox"/>	UOUT	double[]	3	Km/sec	Bulk Velocity
12	8	<input checked="" type="checkbox"/>	FNOUT	Double		cm ⁻³	Electron Density
13	9	<input checked="" type="checkbox"/>	FPOUT	double[]	9	ergs cm ⁻²	Pressure Tensor
14	10	<input checked="" type="checkbox"/>	FHOUT	double[]	3	ergs cm ⁻² s ⁻¹	Heat Flux Vector (GSE)
15	11	<input checked="" type="checkbox"/>	TROUT	Double		Deg K	Electron Temperature = 1/3 trace of the diagon
16	12	<input checked="" type="checkbox"/>	ETTRT	Double			Electron Temp Anisotropy = Tpara/Tperp
17	13	<input checked="" type="checkbox"/>	DEIG	Double			Normalized Gyrotropy
18	14	<input checked="" type="checkbox"/>	COSB	Double			Cosine of the angle between pressure tensor pr
19	15	<input checked="" type="checkbox"/>	EIGVAL	double[]	3	Deg K	Eigenvalues of diagonalized pressure tensor divi
20	16	<input checked="" type="checkbox"/>	CC3	double[]	3	eV	Hi, mid, & lowest energy electron channels > SC
21	17	<input checked="" type="checkbox"/>	POTNEW	Double		eV	Spacecraft potential
22	18	<input checked="" type="checkbox"/>	BX	Double		nT	1-min averaged magnetic field BX
23	19	<input checked="" type="checkbox"/>	BY	Double		nT	1-min averaged magnetic field BY
24	20	<input checked="" type="checkbox"/>	BZ	Double		nT	1-min averaged magnetic field BZ
25	21	<input checked="" type="checkbox"/>	INSET	Integer			Number of energy channels above spacecraft po

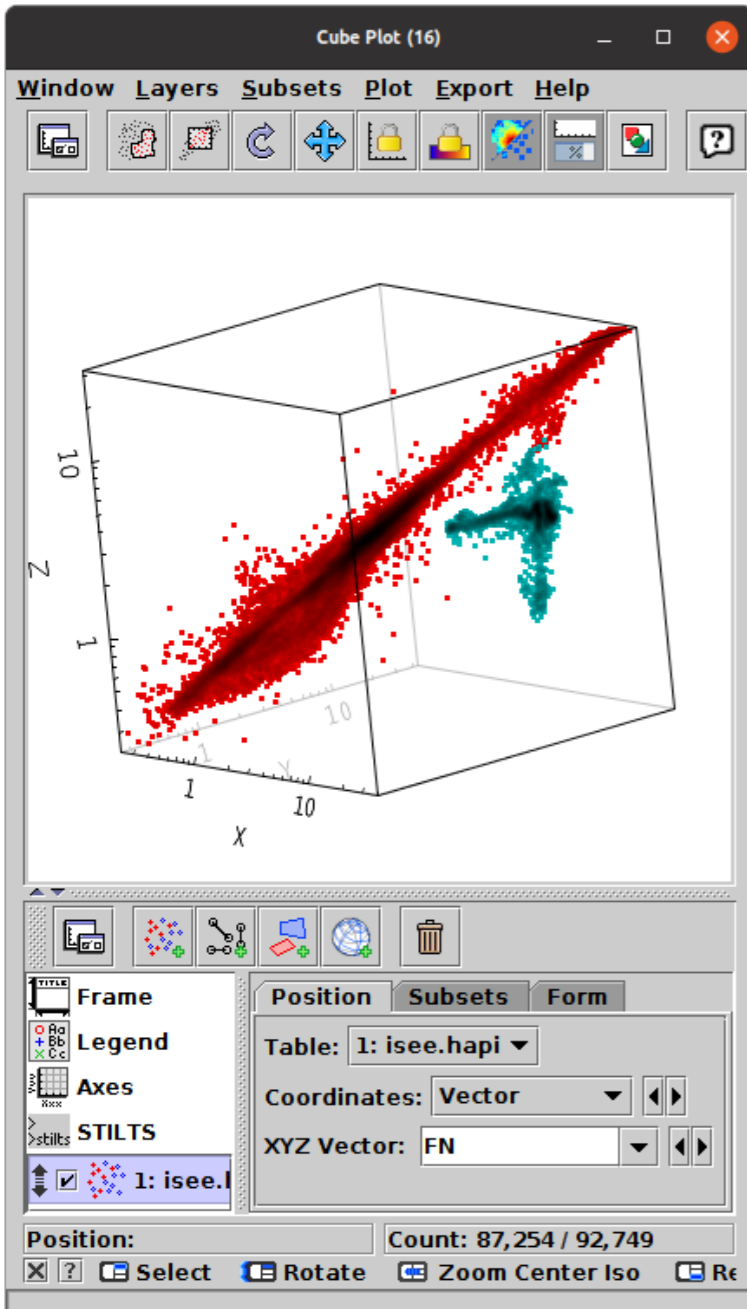
CDAWeb ISEE_H0_FE data

Heliophysics Example: Analysis



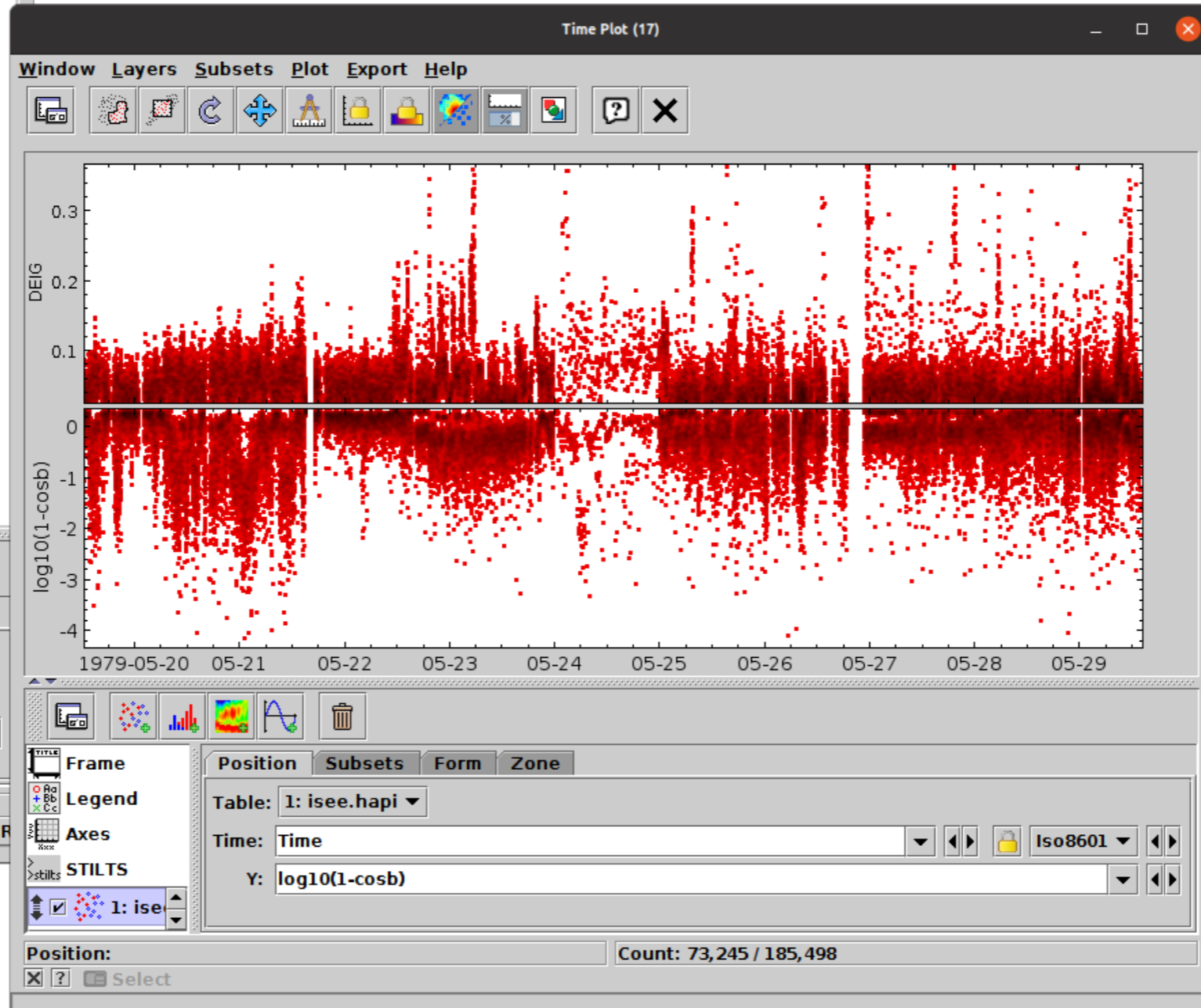
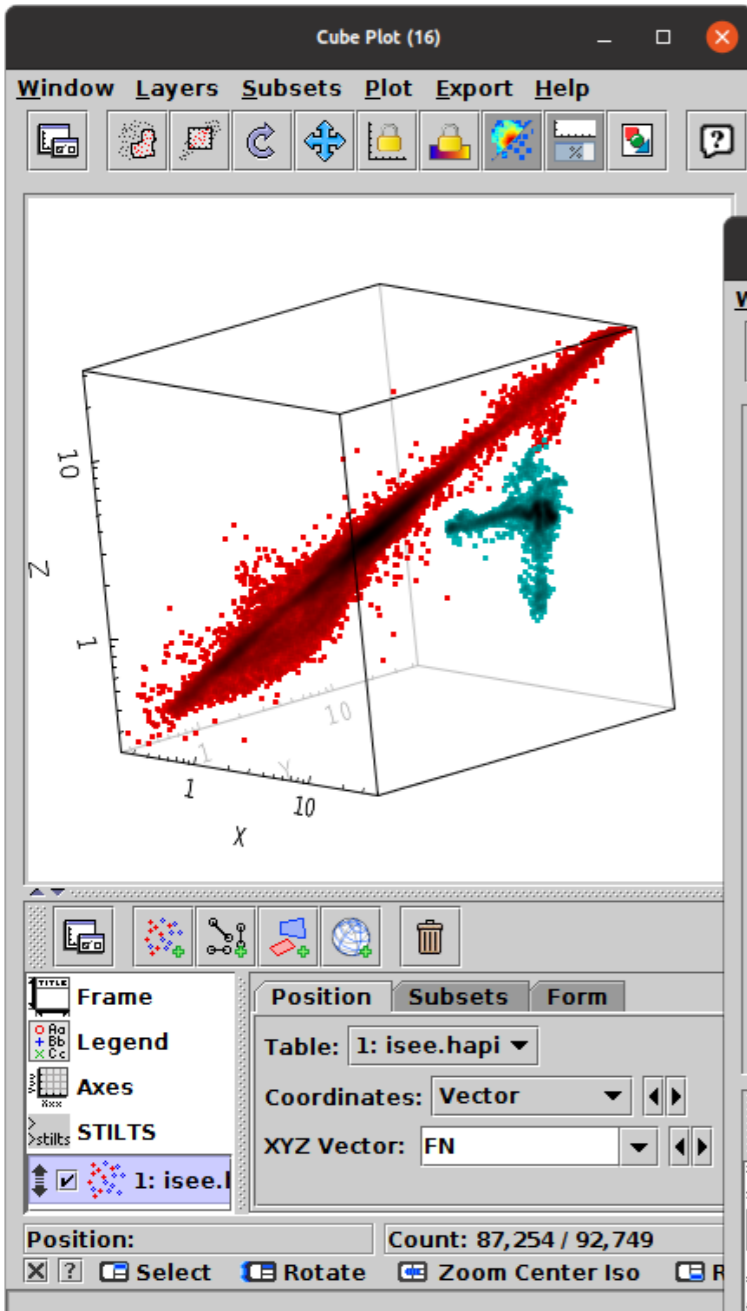
CDAWeb ISEE_H0_FE data

Heliophysics Example: Analysis



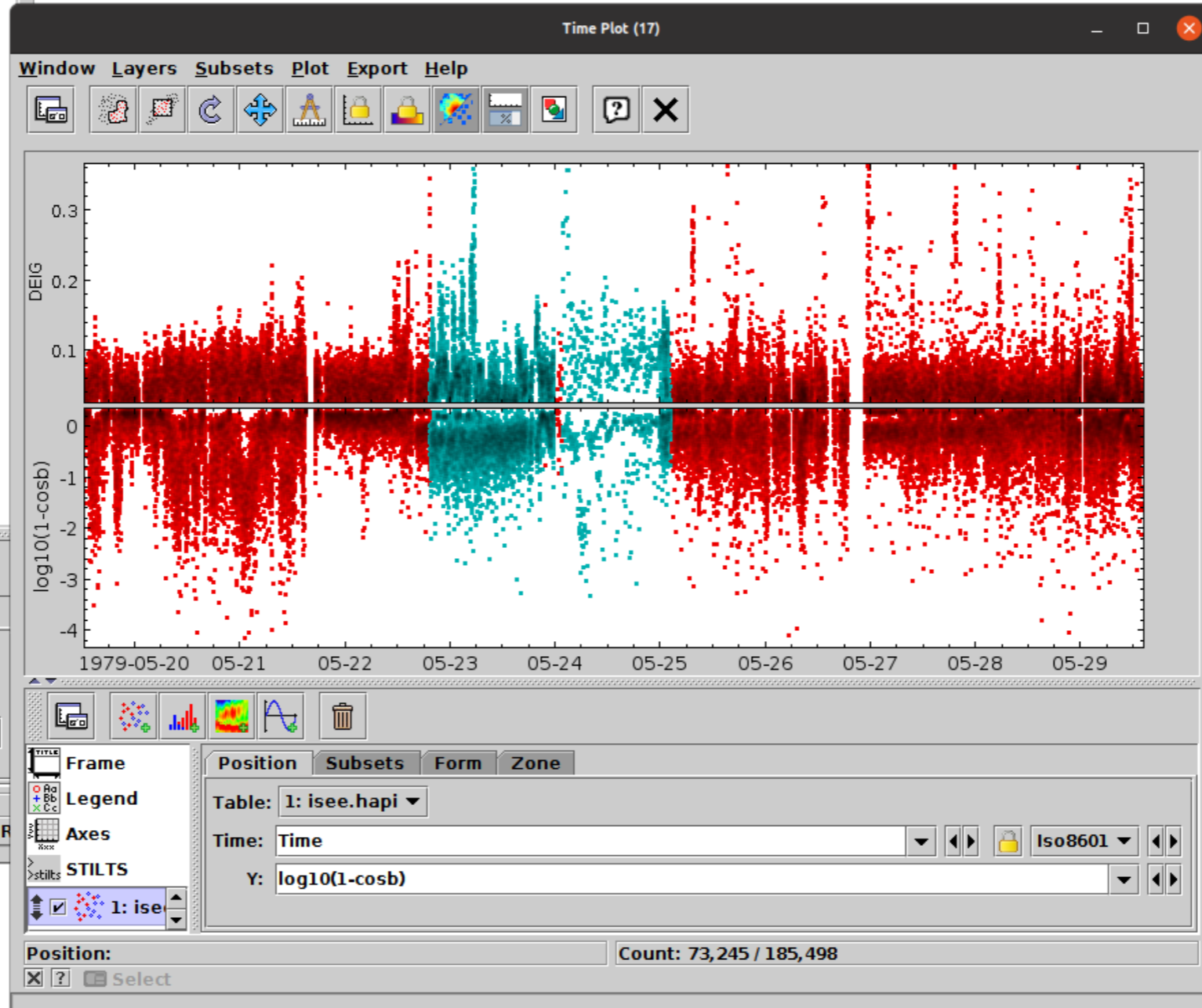
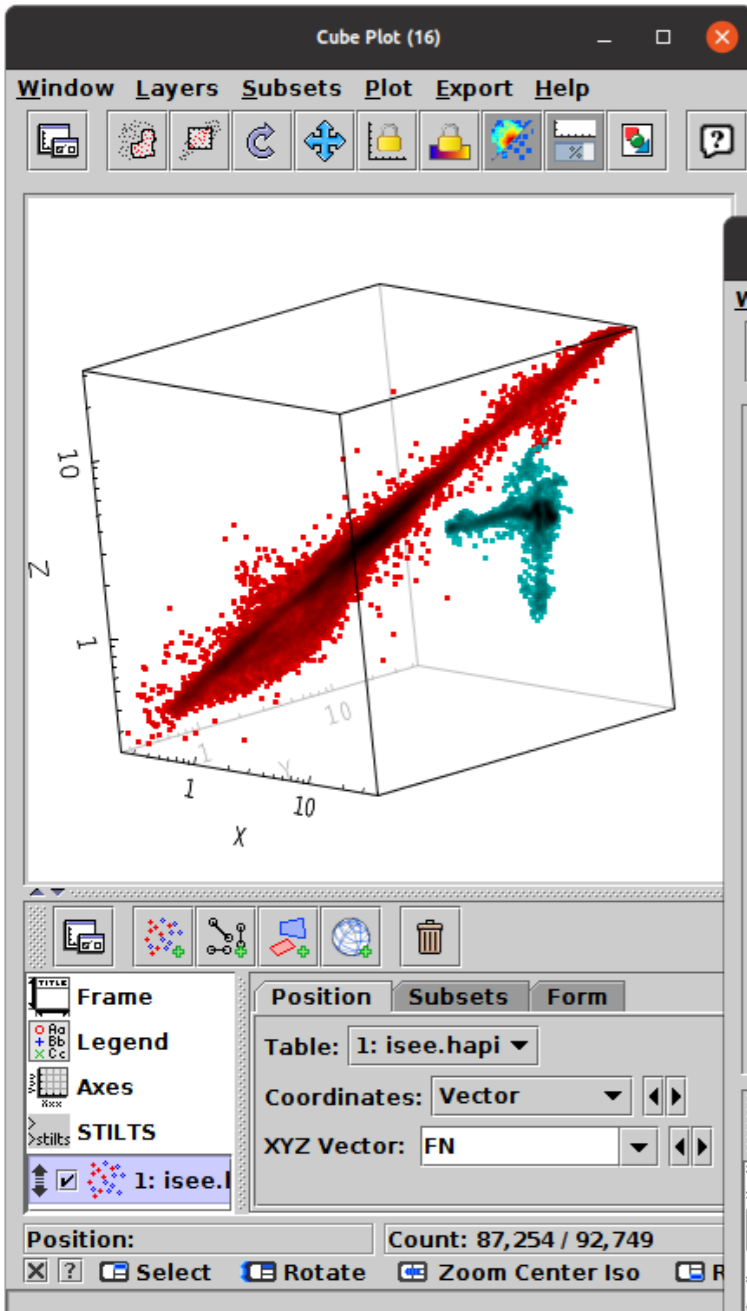
CDAWeb ISEE_H0_FE data

Heliophysics Example: Analysis



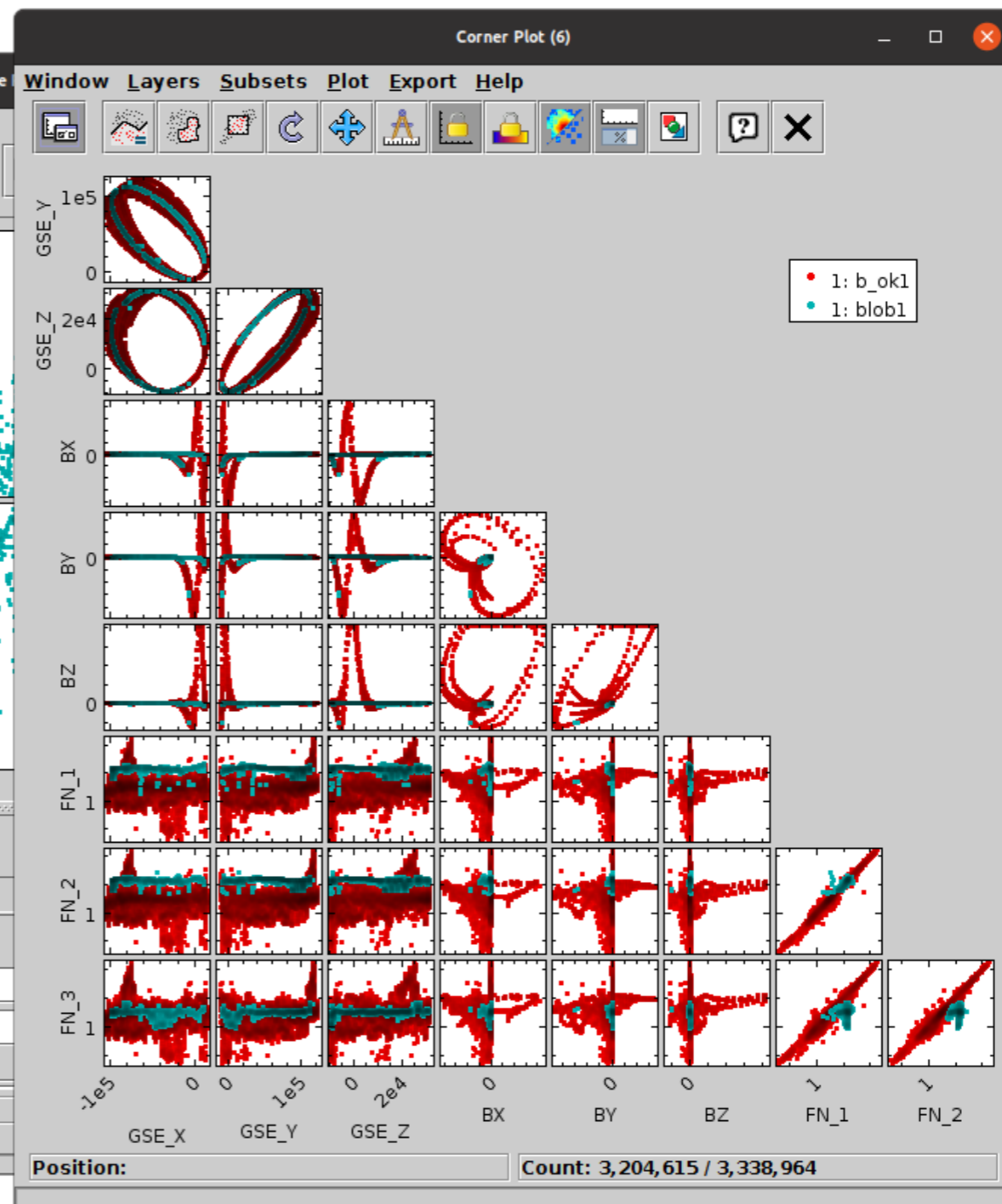
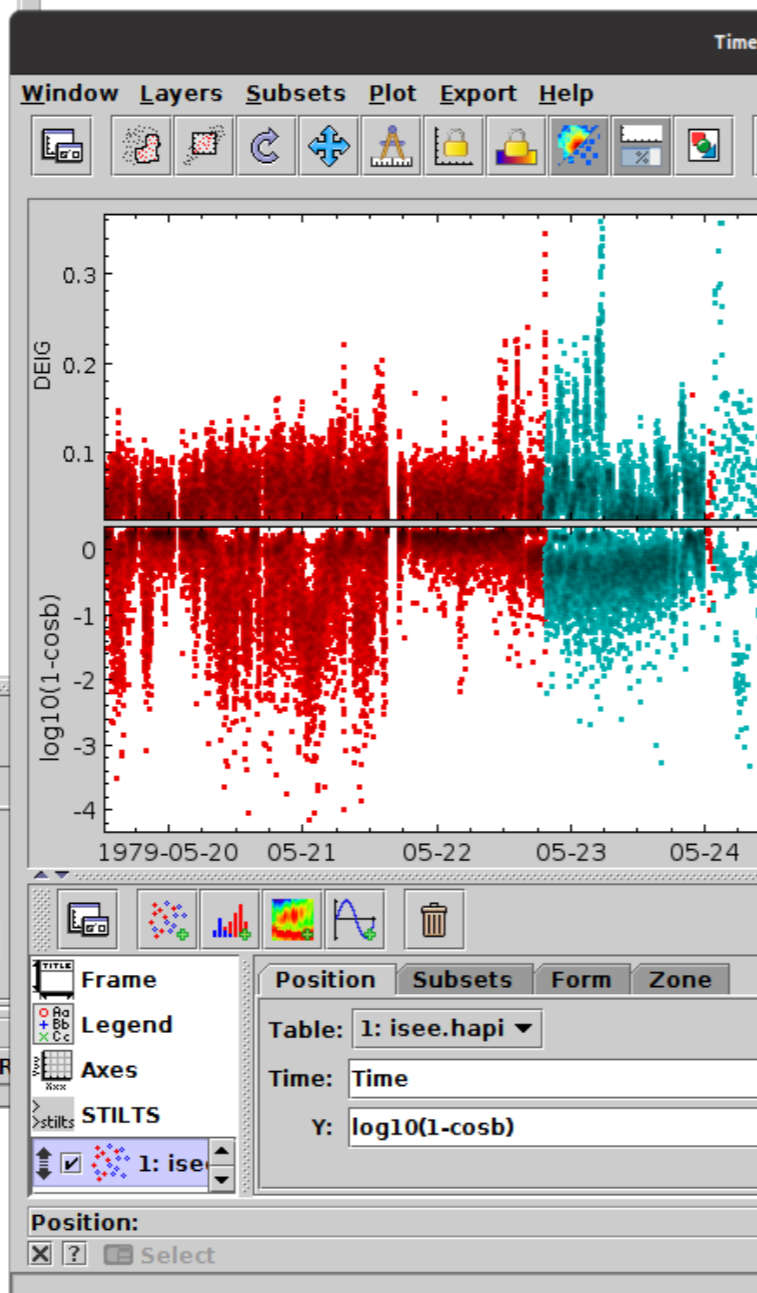
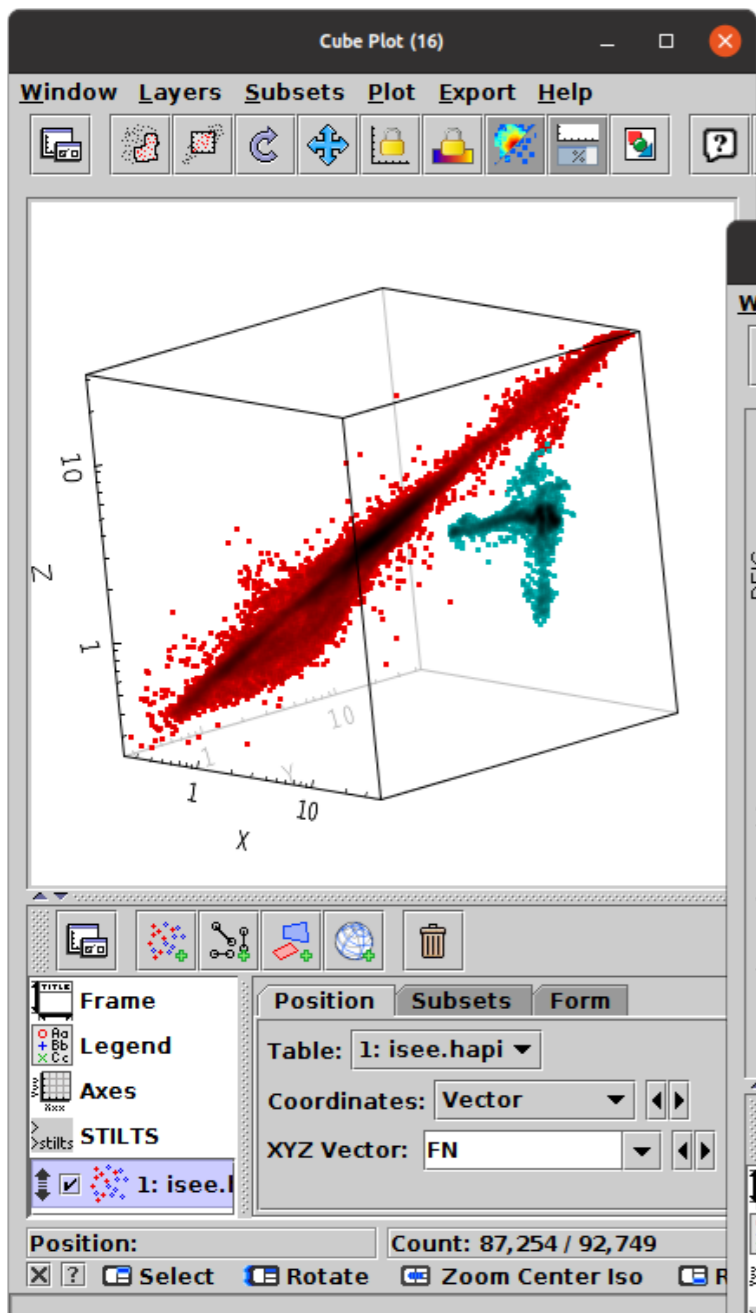
CDAWeb ISEE_H0_FE data

Heliophysics Example: Analysis



CDAWeb ISEE_H0_FE data

Heliophysics Example: Analysis



CDAWeb ISEE_H0_FE data

Conclusion

Summary

- TOPCAT is a powerful data analysis tool, established in astronomy
- It has some heliophysics-specific features ...
- ... maybe it should have some more?
- Please talk to me if you're interested in using it with helio data

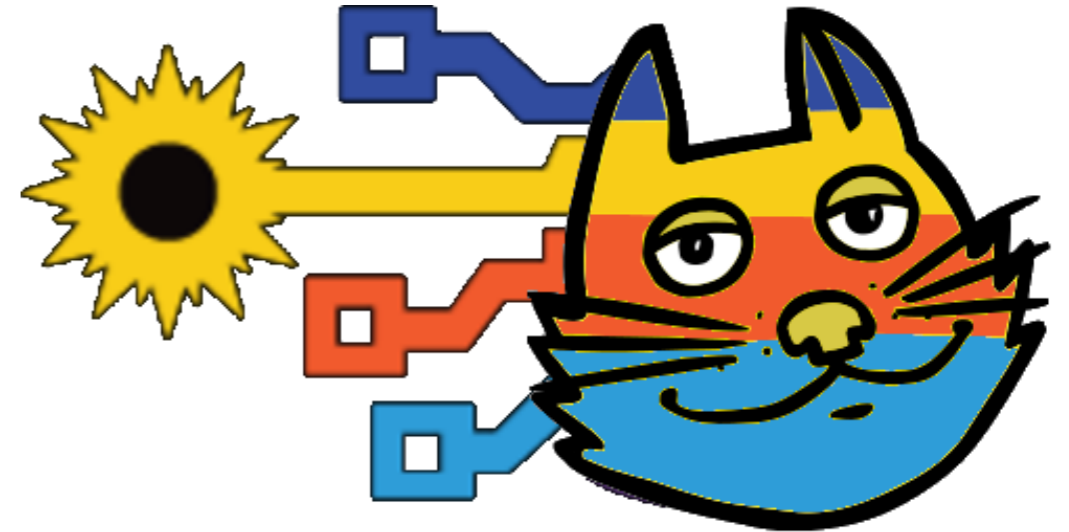
Downloads and full documentation:

<http://www.starlink.ac.uk/topcat/>

(including [TOPCAT/HAPI intro video](#) — extended version of this talk)

Support by email:

- on list: topcat-user@jiscmail.ac.uk
- in person: m.b.taylor@bristol.ac.uk



All questions and feedback welcome!